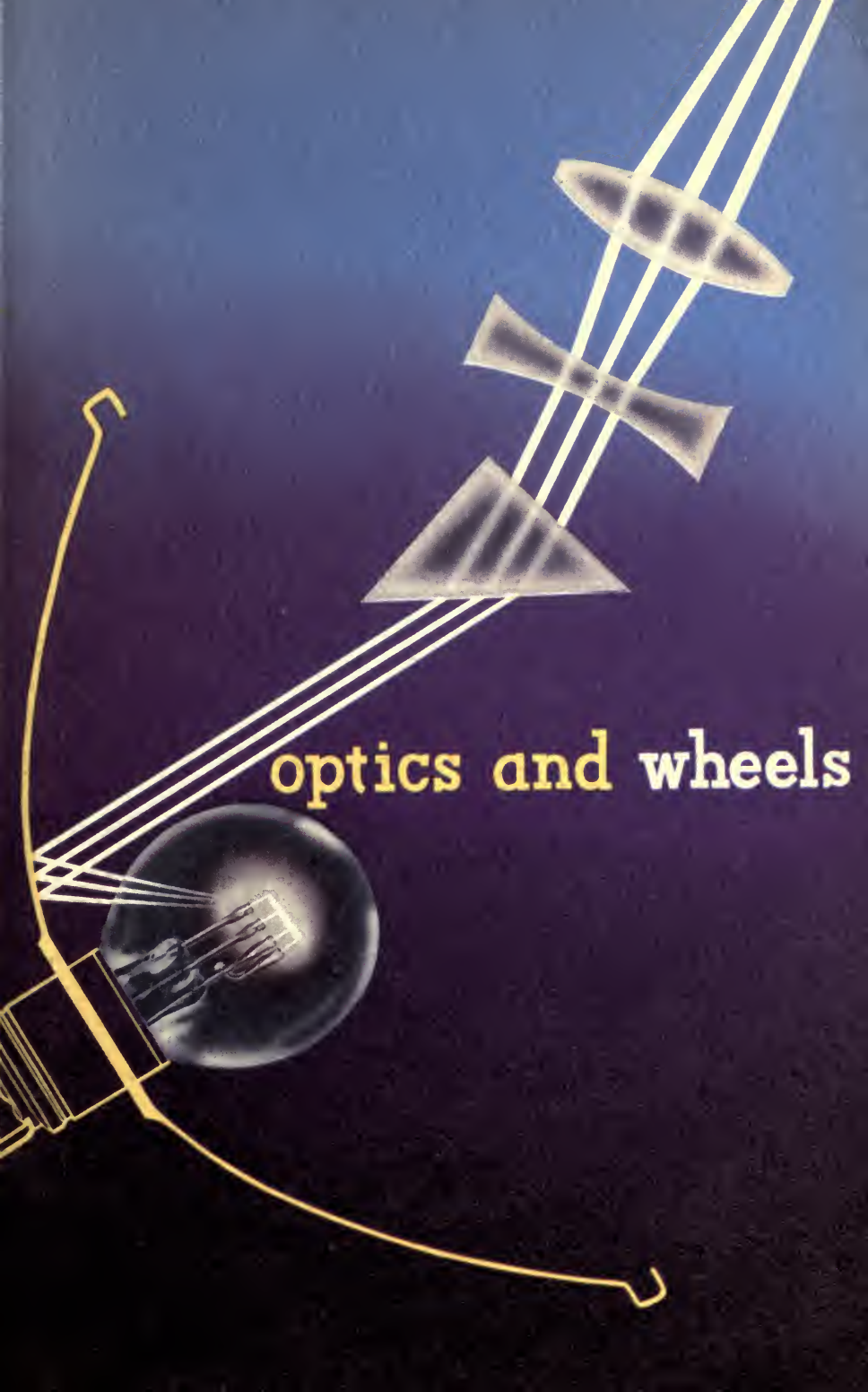
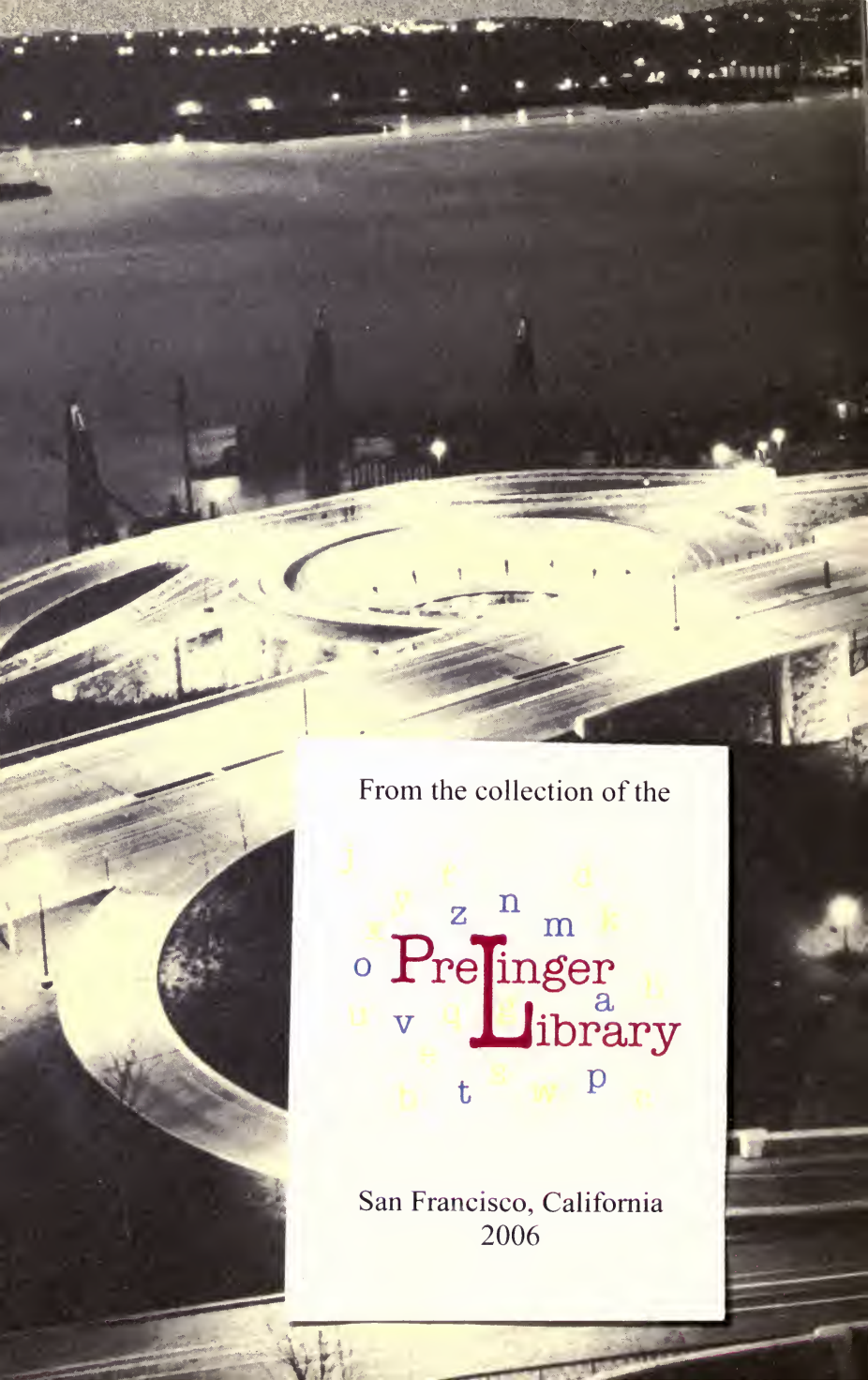




optics and wheels

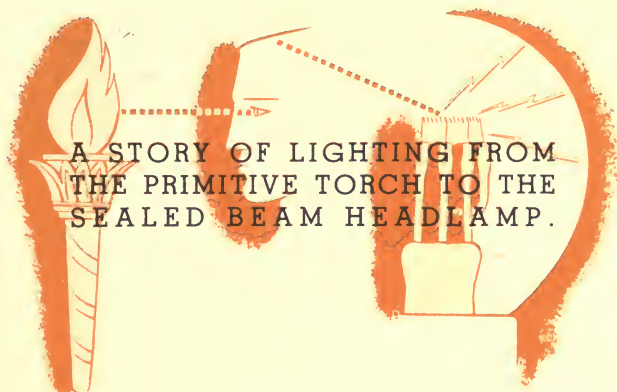


From the collection of the

Prelinger
Library

San Francisco, California
2006

OPTICS AND WHEELS



A STORY OF LIGHTING FROM
THE PRIMITIVE TORCH TO THE
SEALED BEAM HEADLAMP.

*Technical Data Department
Research Laboratories Division*

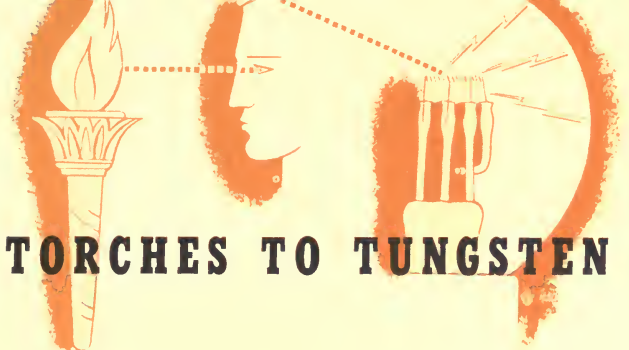
7th Printing

Published by
GENERAL MOTORS, DETROIT

FOREWORD

FROM the beginning of the industry, all branches of science have contributed to the continuous improvement of the automobile, making it more dependable, more economical, safer. The science of optics, dealing with the nature and properties of light, is no exception.

Our knowledge of science is valuable only when it is usefully applied. The following pages show how the scientific facts of optics and light have been applied to solve the problem of safer night driving through the development of the "Sealed Beam" headlamp—a co-operative project undertaken jointly by the automobile industry, lamp manufacturers and highway safety groups.



TORCHES TO TUNGSTEN

PREHISTORIC man contributed many of the fundamentals upon which modern man depends for his present civilization. The discovery of the wheel, the cultivation of plants, the use of tools and the use of fire are all things which we take for granted. All of them represent tremendous advancements. They were the results of sound thinking and venturesome experimentation by unknown prehistoric men.

The caveman, some fifty thousand years ago, began man's winning battle over darkness. Some prehistoric man, more imaginative than the rest, plucked a burning brand from his fire and invented the torch. Light and fire came to symbolize all those things in life that were good and clean, the things men valued. Worship of the sun as the light giver spread to many ancient tribes. Darkness became the grim symbol of the unpleasant and feared and even of death itself. The rites of the fire worshippers, closely akin to sun worship, called for so much fire that whole countries were denuded of forests to supply the fuel. These religions have long

since vanished from civilization, but their symbolism remains and man has never ceased to search for means of lighting the darkness.

Until rather recent times the source of all artificial light was fire. The sun was the only important source of light which did not come from fire. The surface of the sun is 10,000 degrees Fahrenheit, and the light comes from this incandescent body. It is the light from the sun which makes life for man, animal and plant possible on our cold world, and it is this light which man has constantly tried to duplicate. Converting night into day makes man inde-





pendent of the hour of the day or the season of the year. He can carry out his work and his recreation with less regard for the sun's light.

Since the dawn of history many fuels have been used for lighting: wood, pine-knots, vegetable oils and waxes, animal fats, gas and petroleum. All of these fuels contain carbon and most of them hydrogen. The light given off as they burn is due to incandescent particles of carbon in the flame.

At first, lamps were stone or clay vessels which held oil, many of which were highly decorated. The early effort in developing the lamp was put into making the lamp an object of beauty. Very little effort was put into making the lamp a better light producer.

The next step was the use of solid fuels in the form of a candle. It is said that the Phoenicians invented the candle long before

the Christian Era. These first candles were made with a wick surrounded by beeswax or substances obtained from plants. It was not until about 200 B.C. that the tallow candle made from animal fat was used. About 1750, spermaceti, a wax-like material from the whale, came into general use and created a large industry. Many of the early fuels smoked and had bad odors when they burned. This was a penalty man paid for light.

The first major discovery in lighting in thousands of years was made by accident. A French chemist was heating a bottle over a flame when the bottom cracked and fell out. The glass was hot, so he dropped it over the flame. At once the flame became bright and steady, and the lamp chimney was born. This was in 1783, just seven years after the Declaration of Independence.

From that time on, improvements came more rapidly as a result of research in many fields. Gas was distilled from coal and piped to light streets, homes and stores. An incandescent mantle was soon added by Welsbach, who found





that certain earths glowed brilliantly white when heated in the normally blue gas flame. The gas mantle is still used and is most familiar on the gas lanterns used by campers and hunters.

None of the above lights had lent itself for use on the carriages and wagons of the day. Of course a few candle lanterns had been used, but it was not until petroleum became an article of commerce that lights became practical on moving vehicles.

In 1859 Colonel Drake drove the first oil well through 69 feet of Pennsylvania soil. The first attempts to use crude oil produced a black, smoky flame. Before Drake drilled his first well chemists had found that an oil suitable for lamps could be obtained by distilling crude oil. Kerosene, or coal oil, as it was sometimes called, immediately became the preferred fuel for lamps on ships, carriages, in homes and offices. That kerosene lamps could be made portable made them useful on vehicles.

In the days before street lighting, people were often guided home at night by "linkboys" carrying rushlights. This was an early

attempt at providing a light to guide travelers at night. Oil and candle lamps were placed on horsedrawn carriages when roads were traveled at night. The stagecoach was often equipped with lights. These first carriage lamps were used, not to light the road ahead, but to serve as a warning to pedestrians and oncoming vehicles, and to provide light to enable passengers to get in and out with safety.

This was the status of lighting when the automobile industry was getting started in the 1890's. The first horseless carriages either had no lights at all or adapted kerosene lamps from horse-drawn carriages. Soon, however, a new light source became available through the work of Major Morehead, a former officer in the Confederate Army, Mr. T. L. Willson and sev-



eral of his associates. As part of an investigation to obtain aluminum from clay in North Carolina, lime and coal tar were mixed in an electric furnace. The hot residue was thrown into a bucket of water to cool. At once, a gas with a sharp, distinct odor was given off. Thinking it might be hydrogen, the experimenters ignited it with a piece of burning waste. The gas burned with a brilliant flash. Chemical analyses showed the gas to be acetylene, and the material to be calcium carbide. A plant was soon built near Niagara Falls to manufacture calcium carbide for lighting purposes. Acetylene is at present used for welding and as a starting point for several synthetic chemical products, including one form of synthetic rubber.

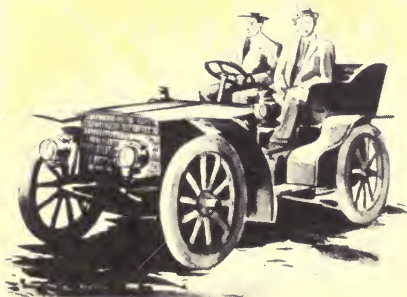
Acetylene was well adapted for vehicle illumination. It could be easily generated by adding water to calcium carbide, which was easy to make. It burned with a brilliant, white flame almost twelve



times as bright as that obtained from coal gas.

The first acetylene lamps were used on bicycles and incorporated the gas generator in the lamp. When these lamps were placed on the early automobiles, the gas generator was likewise installed on the vehicle. Later it was discovered that acetone absorbs acetylene under pressure just as a sponge absorbs water. Thereafter, acetylene was stored in cylinders. These cylinders were used until empty and then exchanged for full ones.

All of the sources of light discussed up to this point depended upon a flame, the burning of a solid, a liquid or a gas. This had been the sole source of artificial light since the beginning of time. With the discoveries in methods of generating electric power, men began their search for ways of using this source of power for producing light. Electric arcs were discovered and used for street lighting, but they had no place in



portable systems. In 1879, Thomas Edison announced his discovery of the carbon filament incandescent lamp. From then on we were no longer dependent upon fire for illumination. The light of the Edison lamp came from an incandescent carbon filament, but there was no burning of a fuel.

In searching for better light sources to illuminate the road, automobile engineers turned to the electric light. The first filaments used in electric lights were frail and broke easily with handling. They were, therefore, unsuited to the automobile. Now that organized industrial research was working on the problem, developments in lighting were coming rapidly. More progress was made in a single lifetime than had been made in all the thousands of years which had preceded this period.

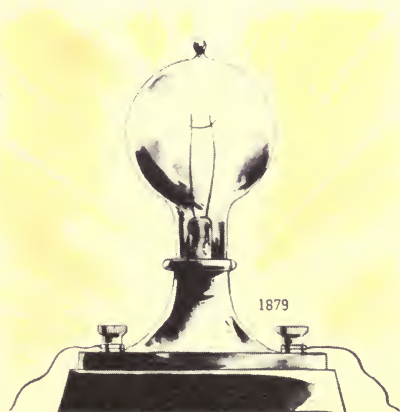
As a wire is heated, it first gets warm, then turns red, and finally, when it is hot enough, it glows brilliantly. Carbon had been chosen as the filament of the Edison lamp because it could be heated to a high temperature in a vacuum without melting. In attacking the problem by research, other materials with a high melting point were tried.

Tungsten is one of the hardest of all the metals and melts at 6,000 degrees Fahrenheit. It is used in tool steels to make a hard material that does not lose its cutting edge. It is also used in one of the newest cutting materials, tungsten car-

bide, which is almost as hard as a diamond.

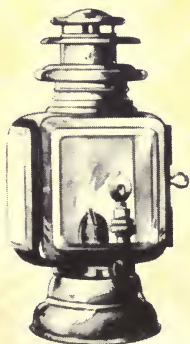
Since tungsten is normally very brittle, the first tungsten filament lamps were even more frail than the carbon lamps. About 1910, Dr. W. D. Coolidge discovered a method of making ductile tungsten wire. A coiled filament of this tough, ductile tungsten, combined with a gas-filled lamp developed by Doctor Irving Langmuir, gave a highly efficient and strong incandescent bulb which soon was universally used for electric lighting. It was strong enough to be used in automobile headlights. The present incandescent lighting is one of the most important contributions of industrial research as carried out in the laboratories of progressive business.

There had been frequent attempts to use electric lighting on an automobile from almost the beginning of the industry. The first electric lights in cars were placed in the old oil or acetylene lamps.



Since there was no battery or generator on the cars, a dry cell or storage battery had to be used. This made electric lighting expensive and difficult to keep in service. Electric automobiles used carbon filament lamps with the current supplied by the same batteries as were used to propel the vehicle.

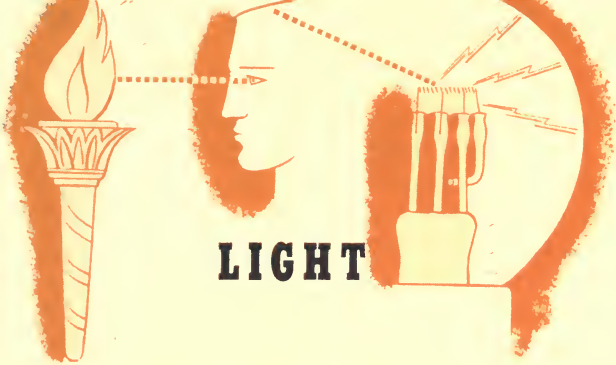
Then, in 1911, the Kettering self-starter was installed on the 1912 model Cadillac. The starter required a storage battery and an electric generator. This same electric system could supply the power for the lights. The combination of the battery starting and ignition system with the new ductile tungsten filament light bulbs gave us our present system of electric lighting on automobiles. Very soon all cars were equipped with this system, and the acetylene and oil lamps were entirely displaced. The electrical system on the automobile is one of the most important improvements ever put on the horseless carriage.



1912 CADILLAC

The illustration shows the 1912 model Cadillac which carried the first electric self-starter as standard equipment. The starter and generator were in a single unit mounted on the engine. The story of the automobile electrical system is told in another booklet in this series, "Electricity and Wheels."

From the first days of the automobile, engineers have given much time to the development of suitable lamps. Improvements in lighting were added to the vehicle to make the automobile a day and night means of transportation. In the first automobiles, lamps were often accessories. In present automobiles, they are an important part of the original equipment. The pages which follow will show some of the problems involved in lighting and how they have been solved.



LIGHT

THE first section of this booklet gives a few highlights on the methods of producing artificial light. While making the discoveries of light sources, man also learned many facts about light. Research on the fundamentals of light produced a wealth of information which could be used to provide better illumination, make more accurate optical instruments and explain many puzzling events in nature. It is usually true that when pure science research adds to our sum of information, industrial research can use the knowledge to improve our products or invent entirely new ones. The result is that our needs are better satisfied and new jobs in industry are opened up. Discoveries in optics are no exception and they make possible many of our most highly prized benefits of modern industrial civilization. The movies, photography, microscopic studies in medicine, astronomy, television, spectroscopic examination of materials and many other fields depend upon light and optics.

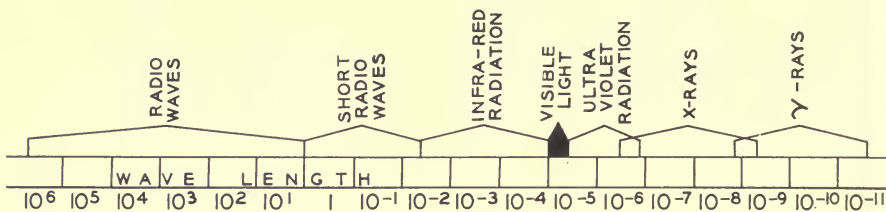
Light seems to be a form of wave motion. It travels at a speed of about 186,000 miles a second.

The sun is about 93,000,000 miles away so it takes the light a little over eight minutes to arrive on the earth. A better idea of the vast distance and the tremendous speed of light is obtained when it is realized that it would take an aeroplane traveling at 300 miles an hour 35 years to cover the distance from the earth to the sun.

Light is usually considered to be transmitted by waves and to be a form of vibration. When the vibration reaches a certain rate, visible light is emitted. X-rays, ultra-violet rays, light, radio waves and heat have many similar characteristics.

The chart on the next page shows the characteristics of electro-magnetic waves of various wave lengths. The long waves are the ones we use for radio trans-





mission. They may be miles long. Infra-red, or heat, waves are longer than the visible rays. The waves that we call light and can see are only a small part of the scale. The entire scale extends over 60 octaves of which only one is visible to our eyes. The ultra-violet rays are shorter than visible rays and X-rays and gamma rays are still shorter. All of these waves travel at the same speed, 186,000 miles a second.

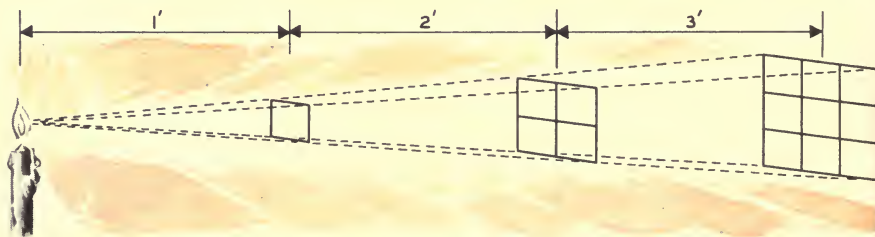
The method of producing light by a heated filament is to get it hot enough so it will radiate light waves. As the filament is heated, it begins to radiate the long, invisible, infra-red heat waves. As it gets hotter it begins to produce the long light waves—red. As it becomes still hotter the waves become shorter and the light changes to yellow and then to white.

The standard of measurement for light is the candlepower, one candlepower being the light given off by the burning of a standard

size candle. This measurement was first used by William Murdock, who was employed by James Watt, the inventor of the steam engine. Murdock was a highly skilled mechanic and an inventor of note. It was he who showed the world how to use gas lighting. He compared his gas light to the then common light source, the candle, with which everyone was familiar. One candlepower is still the fundamental light unit.

Another interesting property of light is the variation of its intensity with distance. "Light varies inversely as the square of the distance," as the physics books say. This means that at twice the distance the light intensity is cut to one-fourth. This is easily understood when it is realized that the same quantity of light must cover four times the area. At three times the distance the intensity is only one-ninth.

The amount of light on a surface one foot away from a standard



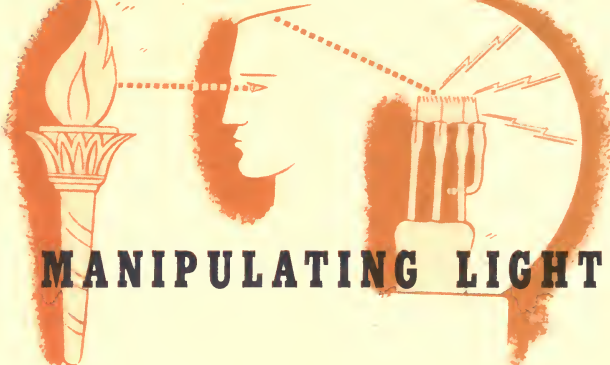
candle is one foot candle, a fundamental unit of light intensity on a surface. At two feet from the candle the light intensity is one-fourth of this amount or one-fourth of a foot candle. To illuminate a surface or object at a distance, therefore, requires a very much stronger light source than is needed if the object is near the source. This is an important factor in automobile headlight design. The part of the light beam which is expected to reach far down the road must be much more brilliant than that which is only expected to light the road in front of the car. If the road is to be evenly illuminated, the portions of the beam which reach farther and farther down the road must be brighter and brighter. Every time the distance is doubled, the light intensity must be multiplied by four. Light which reaches the road far ahead of the car must be hundreds of times as bright as that which reaches the road directly ahead

if the road is to be illuminated at the same intensity.

The strength of the light source necessary to see an object does not follow the "square law" and experiments show that it is a much higher power. In fact, when the distance is doubled, the light necessary to illuminate an object is increased over twelve times. The exact increase depends upon many factors including the size and color of the object, the condition of the observer's eyes and the per cent of light reflected by the object. One reason the "square law" does not directly apply to seeing distances is that the light has to reach the object and then be reflected back to the observer's eyes.

This is the reason it is necessary that automobile headlamps furnish a powerful beam which reaches far down the road. The following pages will explain the shape of the light beam which is desired and the optical devices necessary to produce it.





MANIPULATING LIGHT

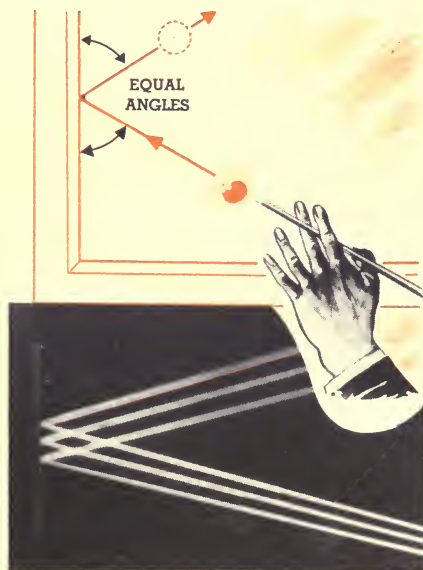
OPTICS is the science dealing with the nature and properties of light. One of the first laws of light is that it travels in a straight line. However, man early learned that it could be bent and reflected by various optical devices. A number of the fundamental optical principles are used in automobile lighting.

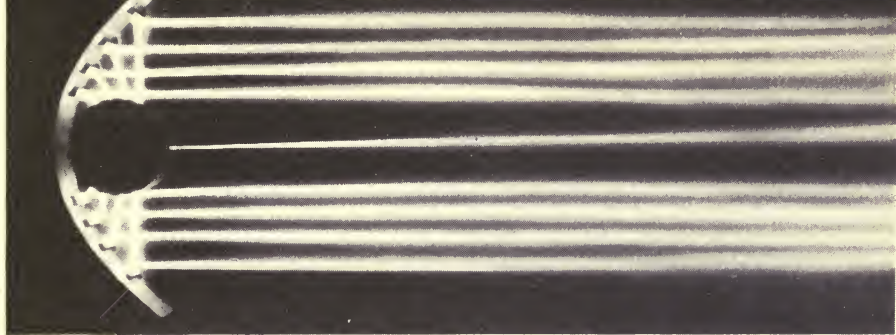
That light can be reflected is perfectly obvious and we find examples everywhere we look. The fact is, we see more reflected light than we do light from a

direct source. In reading this page you are depending upon the reflection of light from the paper.

The law of reflection can be best illustrated by a simple flat mirror. When a ray of light strikes the mirror at an angle, it is reflected from the mirror at the same angle. Light bounces off the mirror just as a billiard ball is bounced off the cushion of a billiard table. The illustration shows the similarity between the action of the ball and that of the beam of light.

There are both diffusing and bright polished reflectors. Diffusing reflectors scatter the reflected light in all directions. White blotting paper, which reflects 60 per cent of the light, is a diffusing reflector. Others are snow with a 70 to 80 per cent reflection factor, and grass and green crops with a 5 to 10 per cent factor. The high reflection factor for snow is the reason snow-blindness often affects people travelling over wide areas of sunlit snow. Green leaves of growing plants absorb the sun's energy and store it in a chemical form for man to use. That is probably the reason 90 to 95 per cent





is absorbed and only a small portion reflected.

A highly polished metal surface is an extremely good reflector. Polished silver and aluminum are the most used surfaces. The best metal surfaces may have a reflection factor of as high as 96 per cent.

To concentrate the light from a single source, such as the filament of an electric bulb, a curved reflector of polished metal can be used. Let us take a series of small reflectors and place them around an electric light bulb. If the reflectors are turned so that the reflected light comes from them in parallel beams, the light in the beam will be greatly intensified. We will have the direct rays from the light bulb plus the light from all the small reflectors.

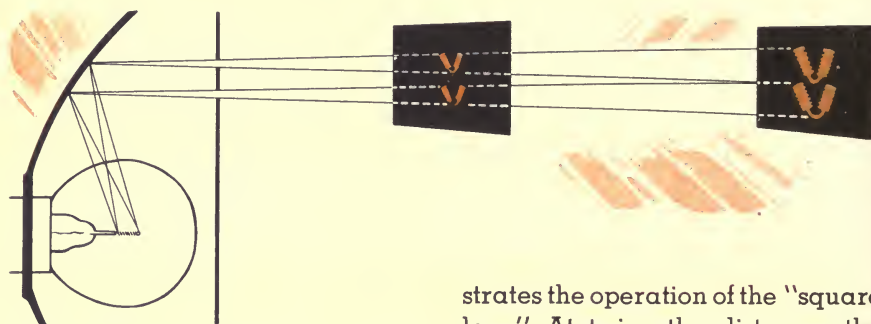
We could substitute a curved surface for the small reflectors and reflect an unbroken beam. The shape of this surface would be a paraboloid, and the point where the light filament was would be the focus. The fact that a parabolic reflector will send out parallel rays when the light source is at the focus was known in ancient times. It is said that the Greek

philosopher, Archimedes, used huge curved mirrors to concentrate the sun's rays on the Roman fleet and thus set it afire. This happened in 212 B.C. when the Romans attacked Syracuse.

The automobile headlamp uses either a parabolic reflector or a slight modification of it to obtain a concentrated light beam. Such reflectors are made either of brass with a silvered surface or of glass with an aluminum surface, and can multiply the light from a low candlepower filament to as much as six thousand times the candlepower of the light source.

However, reflectors become tarnished and dirty so that much of the light may be absorbed or wasted, thus reducing the light intensity to such an extent that night driving is dangerous. Fortunately, reflectors can be polished or replaced if found defective, thereby considerably improving the efficiency of headlighting on older cars.

Even this problem has been conquered, through science and research. The reflector interior has been effectively sealed from dust and moisture, thereby preserving permanently the reflecting sur-



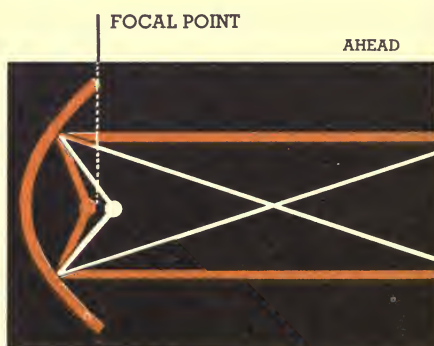
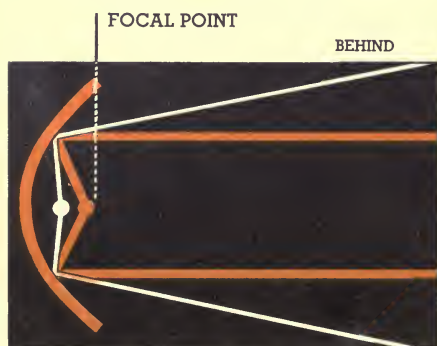
face. This development, known as "Sealed Beam Lighting," was introduced in automobile headlamps on 1940 models.

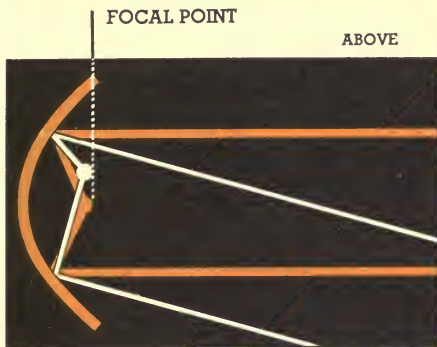
We can demonstrate what happens to the light from any spot on a parabolic reflector by a simple experiment. If a mask with a small hole in it is placed in front of a parabolic reflector and a light bulb, the light from only one small portion of the reflector can be studied. If a screen is placed in front of the reflector, an image of the filament will be projected on the screen. As the screen is moved away from the reflector the image becomes larger. At twice the distance, the area of the image is four times as large. This demon-

strates the operation of the "square law." At twice the distance, the same amount of light must illuminate four times the area, so that the intensity will be cut to one-fourth.

If additional holes are cut in the mask, exposing small areas from the top, bottom and sides of the reflector, the images of the filament will overlap. As more and more of the reflector is exposed, the images blend together. When the mask is completely removed a round spot of light is formed by the images from all parts of the reflector.

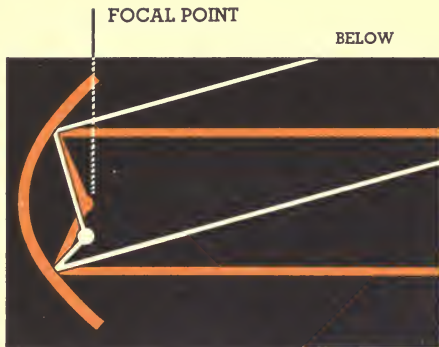
The parabolic reflector will reflect parallel beams of light only when the filament is at the focus. When it is at any other point the beam is entirely changed. If the





filament is behind the focal point, the reflected rays are diverging. If the filament is ahead, the light is narrowed to a point where the beams cross and separate. This fact made it necessary in old-type headlamps to provide a means of focusing the bulb. Since 1929, all bulbs have been so accurately made that the filament is at the focus when the bulb is put in the socket.

If the light filament is above the



focus, the major portion of the beam is tilted down. If it is below the focus, the major portion of the beam is tilted up. We use deliberately offset filaments to control the beam to make it move up and down in the two-beam headlighting system. The shape of the reflector, the type of lens, and the position and shape of the filament can be chosen, therefore, to give the exact beam which is needed to light the road.

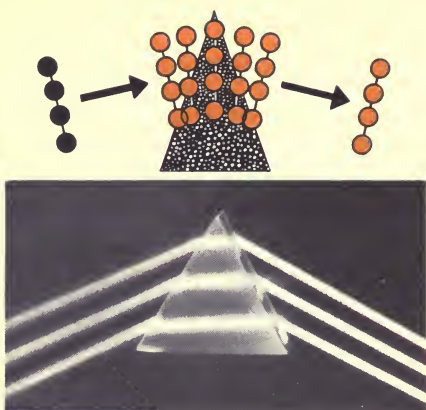
BENDING LIGHT RAYS

IT IS fortunate for us that light can be bent, or in technical language, refracted. In traveling from one transparent medium to another, such as from air to water, a light beam is bent. If this were not so, our eyes could not focus light coming to them and we would not be able to see an image.

Refraction, or bending, takes place when light passes from one substance to another because light travels at different speeds in dif-

ferent mediums. The speed is highest in a vacuum and almost as fast in air, or about 186,000 miles a second. It is only about three-fourths of this speed in water and two-thirds in glass.

A mechanical explanation of refraction can be made by using the billiard table. Suppose we mount a row of balls solidly on a shaft to represent a light beam. The balls will roll freely straight down the table if given a push.



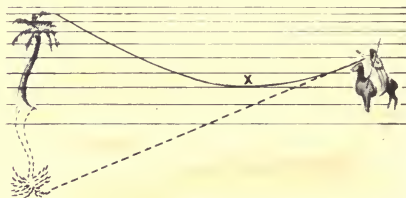
If we put a retarding force, such as a large triangle of coarse sandpaper, in the path of the balls, the direction of their rolling will be changed. The speed of the balls over the sandpaper will be slower than that on the felt of the table. The ball which rolls over the longest piece of sandpaper will be retarded most. When the string of balls leaves the sandpaper triangle, the motion will be changed in the direction of the wide side of the triangle.

A prism is a triangular-shaped wedge of glass. If we send a bundle of light rays through a glass prism, the same action will take place and the emerging rays will change direction.

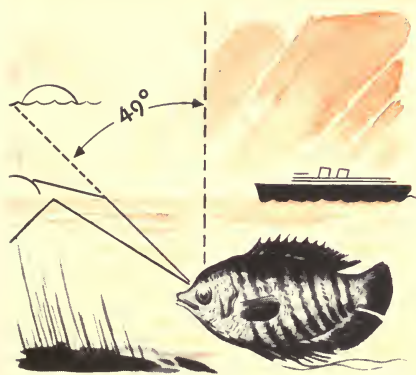
This is refraction. Many peculiar optical effects can be explained by refraction. The air itself is of varying density from the ground up. The light which reaches us from the sun is, therefore, bent in coming through the envelope of air which surrounds the earth. For this reason, we

actually see the sun after it has set. About eight and one-half minutes after the sun has really gone below the horizon we can still see it. Likewise, we can see the sun for the same time before it rises in the morning.

Mirages, as seen by a thirst-maddened desert traveler, are also caused by refraction. Next to the hot, parched sand the air is considerably hotter than it is above it. The hot air is less dense than cooler air and is less refracting. The light passing through the hotter layers is, therefore, bent less than that passing through the cooler layers. The light from a distant object is bent less and less as it passes from the cooler to the hotter air until it reaches a critical angle marked by X on the illus-

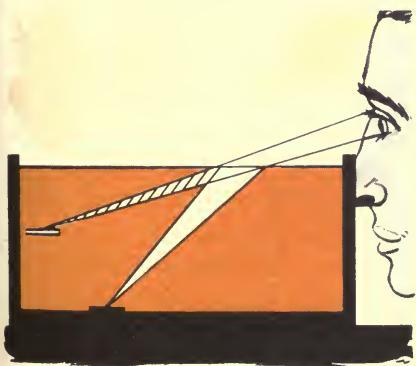


tration. At this point, the image is reflected just as it would be by a mirror-like surface such as a lake. This reflected beam is further bent in passing from the hotter to the cooler layers of air until it reaches the tortured eye of the traveler. The beam reaches the eye from a direction which makes it appear to come from a point below the ground. The image is inverted and seems to be a reflection at the



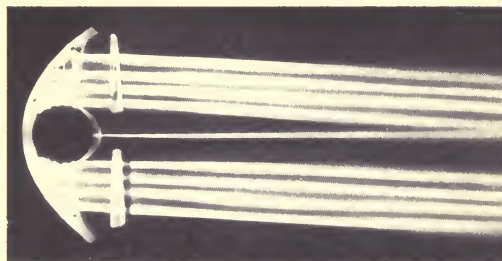
point X from the surface of a lake. This same effect is responsible for what looks like pools of water on a hot road.

A fish obtains a narrow view of the world above because of refraction. It sees the horizons in a cone with an angle to the vertical of 98 degrees instead of 180 degrees, as we see them. A beam of light is bent 49 degrees in passing from air into water. When the sun is setting on a smooth sea it looks to the fish as if it were setting at a point high in the sky. At greater angles the surface of the sea reflects light and it looks like a brilliant mirror.



On the other hand, when we look into clear water, it appears much shallower than it really is. That is a good fact to remember when swimming in strange lakes. A pan of water with a coin at the bottom will be sufficient to prove this to yourself. The light from the coin is bent and makes it appear to be at the position shown by the cross hatched lines.

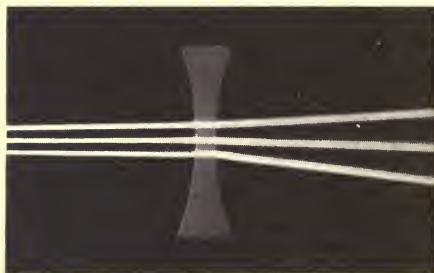
The ability of the glass prism to bend a beam of light is very use-



ACTUAL PHOTOGRAPH OF BENDING LIGHT RAYS

ful in many optical instruments. In our automobile headlamps it is used to change the direction of the light beam which is reflected by the parabolic reflector. The beam may be redirected by prisms to give the right illumination on the road.

Refraction also takes place in lenses. A simple double convex lens is really a series of prism elements. The light from each element is bent according to the angle of the prism. A lens is made so all of the rays concentrate at one point, which is called the focus. This ability of a lens to focus the rays of light from the sun is used in a burning glass and has



been known for thousands of years.

If a lens is made with concave surfaces, the light rays are bent outward and the beam is spread. This is true whether both surfaces or only one are concave. Concave or fluted surfaces are used in headlamp lenses to spread the light beam to cover the road. A broad flat beam instead of a bright round spot is necessary for

proper road illumination.

There are many other types of lenses and prisms used for many purposes. Cameras, field glasses, range finders, microscopes, and hundreds of other optical instruments depend upon our knowledge of lenses. Each of these has been developed to a high degree of perfection by optical research work.

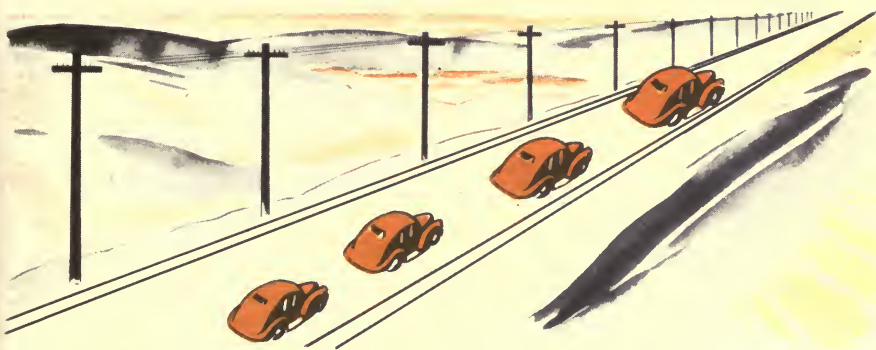
THE EYE IS A SEALED RECEIVING SYSTEM

IN all of the preceding pages we have described the light sources and the methods of controlling them. But the most important element in the system and the receiving device, the human eye, is also an optical device. It is a sealed system with all the important elements protected from exposure.

A diagram of the human eye will show how it receives an image. The eye is made up of a number of optical parts with which we are already familiar. A crystalline lens focuses images on the retina just as a photographic lens

focuses an image on the film. The retina is made up of light-sensitive cells and is an extension of the optic nerve. The center of the eye is filled with the vitreous humor, a transparent gelatine-like mass. In front of the lens is the iris which expands and contracts to regulate the amount of light which reaches the retina. Muscles control the movement of the eye, the focus of the lens, and the size of the iris.

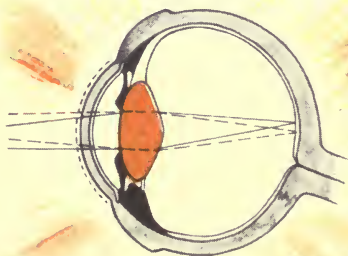
In describing the effects of automobile lighting, a normal eye with good vision is always assumed. If the driver's eyesight is poor and



he needs glasses, the best lighting will be inadequate. Glasses are lenses which correct the optical defects of the eye. Those who use glasses to correct deficiencies of vision that affect seeing on the road, should always wear them while driving.

In referring to lighting, we should always remember that what we are discussing, and the most important factor, is the effect on our eyes. Glare is an example. When light reaches a high enough intensity we say it is glaring. But glare is not a constant quantity. The intensity of light which will cause discomfort from an oncoming headlight on a dark road would be a low intensity light in the daytime. The light from a match is not very bright, but a match close to the eyes in a dark room will be very glaring. Light from the upper beam of a headlamp will cause glare to an oncoming driver while the same beam directed down will not. Many factors affect glare and even one's physical condition has a bearing on the subject.

Things are not always what they seem and the eye can often be fooled. There are many visual illusions to demonstrate this fact. Many of these are caused by peculiarities of our eyes. The illustration shows an illusion. All of the cars are the same height although the most distant car appears twice as large as the nearest one. This is because we are used to allowing for a change in size with distance. The car which is farthest away should be smaller. Since it is not and our eyes still make the accommodation, the car looks larger. This is the type of experience we use in driving to estimate distances for passing and stopping, and it demonstrates how this may be in error.





SEALED BEAM HEADLAMPS

UP to this point we have traced the progress in the development of light sources up to the tungsten filament electric light bulb. We have seen how the use of a parabolic reflector multiplies the light in the reflected beam to thousands of times that of the bulb. That this light could be spread and bent has been demonstrated. The lighting engineer has used this information to produce better and better night illumination for the motor car driver.

Progress has been steady since the automobile industry first adopted the electric starting, ignition and lighting system in 1911. Each year new and better lights have been given to the motorist. Year after year engineers have worked in the dark rooms of industrial research laboratories and on night road tests to develop new and improved systems. Two-filament light bulbs were developed to give a driving and a passing beam. In 1929, these two-filament bulbs were made accurately enough so focusing was unnecessary. Accuracy was soon further improved so that filaments were located to a limit of a few

thousandths of an inch. Optical principles were applied to produce good beam patterns. Each step gave the driver more control over night driving conditions and each was an advancement over the past. If any headlamp produced in the last ten or twelve years is kept in good order it will produce good road illumination. It is only when the electrical and optical parts deteriorate that the lighting becomes inadequate.

During 1937 a new development was started to eliminate some of the difficulties experienced with headlights. An automobile industry lighting committee, working in conjunction with the state motor vehicle administrators, safety organizations, headlight manufacturers and lamp manufacturers, analyzed the requirements of a standard lighting system that could be used on all passenger cars and commercial vehicles. After many experiments had been made, the Sealed Beam Headlight system was developed and introduced on the 1940 models.

The co-operative program had seven major objectives. The list

with the method of solution, is given below.

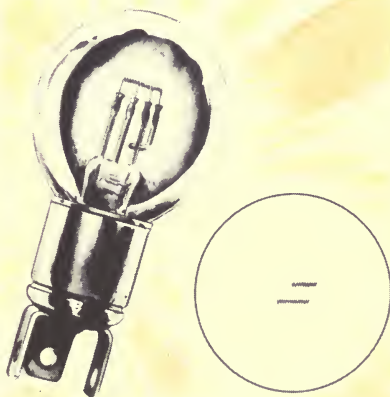
1. The new system must provide the safest possible seeing under all the varying night driving conditions. This meant a two-beam system.
2. It must provide relief from glare when meeting other cars and in cities. The passing beam takes care of this requirement.
3. It must be easy to operate so that the driver will use the right beam at the right time. All cars use a left foot switch for changing from one beam to another and an upper beam indicator.
4. It must maintain its lighting efficiency so that as cars grow older they will have as safe lighting as newer ones. The sealed reflector satisfies this requirement.
5. It must be simple to adjust. Aiming only is required and this is done with no other tools than a screwdriver.
6. It must simplify parts distribution so that owners can get immediate replacement service. The unit incorporating lens, reflector and bulb, which fits any car equipped with the Sealed Beam system, simplifies the number of parts in stock. In addition, as new developments emerge from research they can be incorporated into the unit without affecting its interchangeability and the car owner will get the latest

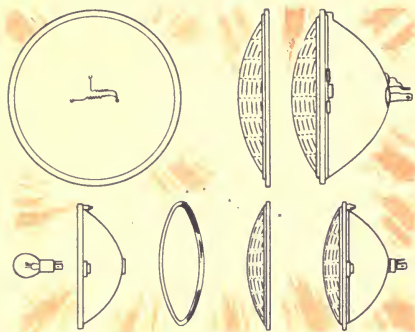
developments when he replaces the unit.

7. It must simplify the work of officials responsible for laws and traffic regulations. Because the Sealed Beam system does not deteriorate, is simple to adjust and easy to aim, it does fit this requirement.

Let us apply the fundamental optical principles which have been taken up in the first of the book to explain the Sealed Beam Headlight. A bulb with two bar filaments is used in a parabolic or modified parabolic reflector. One bar filament is located above and slightly to the side of the other. The lower filament produces the upper beam. The upper filament produces a beam which tilts down and to the right for passing. The action is in accordance with the explanation of the location of the light source in respect to the focus of a parabolic reflector.

One type of Sealed Beam Head-





light uses an assembly made up of a light bulb, a silver-plated brass reflector, a gasket and a glass lens, all sealed together to keep out dust and moisture. A second type uses a glass reflector upon which bright aluminum has been deposited. The glass lens is fused to the glass reflector and the inside filled with argon gas. The filaments are located in the reflector without the use of a separate bulb since the entire unit is a sealed glass bulb. The two types of units are interchangeable

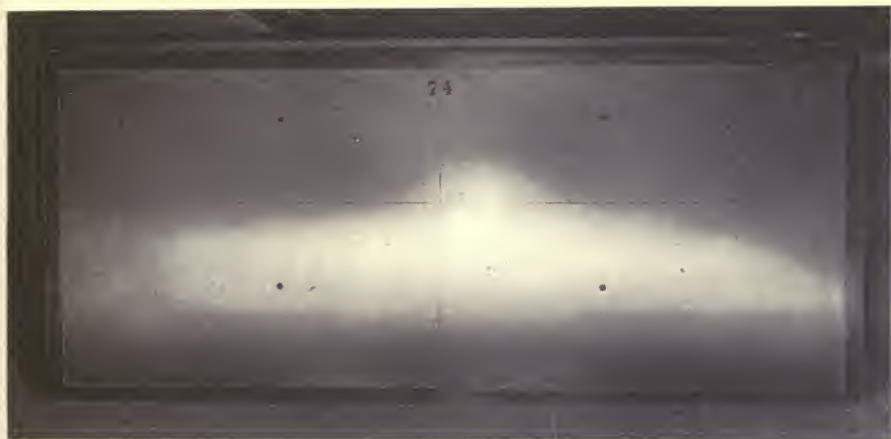
in all respects—optically, mechanically and electrically.

In front of the reflector a lens was developed to produce a lower beam pattern which would give good road illumination with a minimum of glare. The filament life was increased so that replacement would not be necessary as often as with previous bulbs. Since the entire unit of lens, reflector and light source is in one sealed unit, the operation of headlamp adjustment is simplified to that of aiming only.

The beam given off by the reflector is controlled in several ways to build up a beam pattern. Flutes and prisms are used to control the beam in accordance with the principles which we have already seen. If we place a screen 25 feet in front of a headlamp, the beam pattern can be seen. In the upper beam the brightest

ACTUAL PHOTOGRAPH OF UPPER BEAM PATTERN, SEALED BEAM LAMPS



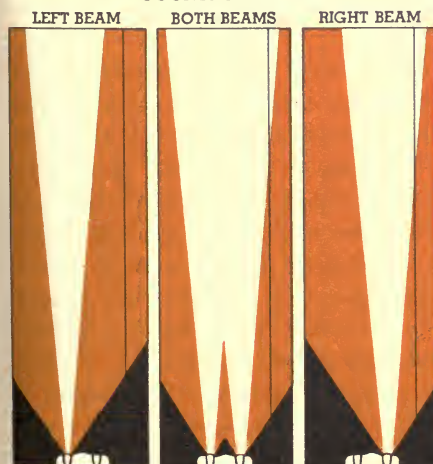


ACTUAL PHOTOGRAPH OF LOWER BEAM PATTERN, SEALED BEAM LAMPS

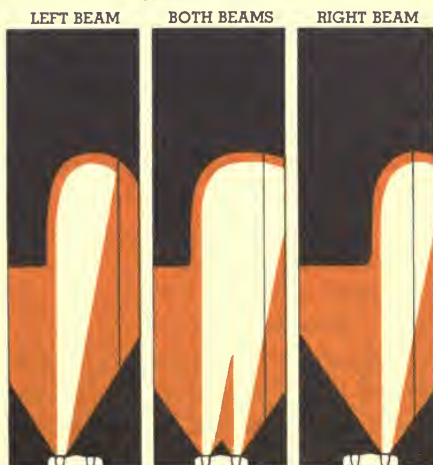
portion is a horizontal, shallow, elongated spot aimed straight ahead and slightly below the center of the lamp. The light fades gradually and evenly on both sides, above and below this hot-spot. This intense center portion illuminates the road far ahead, for its candlepower has been built up many thousands of times by reflection from the parabolic re-

flector and by bending light from the main beam into a spot. Some light is spread to the sides to illuminate the shoulder of the road, signs, curves and side roads. A smaller amount of light is aimed downward, and since it strikes the road near the car and does not travel far, it need not be intense. A small amount of light is distributed upward to illuminate cy-

COUNTRY BEAMS



TRAFFIC BEAMS





clists, railroad crossing signs and overhanging projections.

As seen from above, the upper beams from the two headlights blend together to produce a safe driving beam for open roads with little traffic. The road is illuminated far ahead with sufficient illumination to distinguish dark objects—a parked car or pedestrian in dark clothes. The beam illuminates the shoulders of the road so that we can readily see pedestrians, side roads, signs and curves.

But it is necessary to provide for illumination in traffic which will not cause glare to the oncoming driver. A traffic beam, with many of the same general characteristics of the upper beam except that it is aimed lower, is therefore provided. When you step on the light switch, the upper bar filament is lighted and the lower filament turned off. Since this filament is above and to the left, the beam will be shifted down and to the right.

The pattern on the screen will, therefore, have the bright spot below and to the right of the center of the headlamps. It will hit the road closer to the car and will be out of the eyes of the oncoming driver. The right-hand shoulder will receive increased illumination for signs and pedestrians, thus providing for the driver's safety.

Viewed from above, the high-intensity zones in the two traffic beams blend together and are directed to the right. This beam should always be used in cities and on the open highways when meeting other cars. It is aimed low so that it will not cause glare. The upper beam is purposely aimed up and far down the road for safer night driving on the open highway. If not depressed, it will cause glare to the oncoming driver. The lower beam should always be used when the oncoming driver is within 1000 feet. If his lights glare because they are not properly aimed, look to the

right and guide yourself by your light on the right edge of the road.

For your own safety and that of others, follow the suggestion in the verse:

"Use country beam

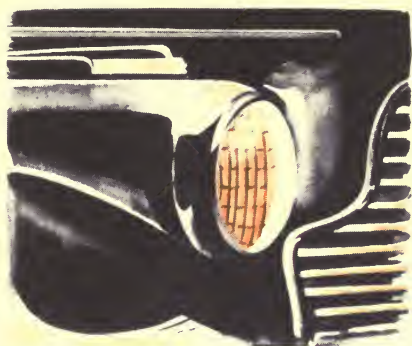
When roads are clear,

Use traffic beam

When cars are near."

The type of headlight used prior to the Sealed Beam will give satisfactory illumination if properly maintained by the automobile owner. Bulbs become less efficient due to the blackening of the glass by filament evaporation. Reflectors become tarnished and coated with traffic film. Lenses become cracked or dirty. Lamps get out of adjustment or aim from the bumps and jolts that a car is subject to in normal usage. Wear, corrosion or defects in the electric wiring, sockets, switches and connections can reduce the voltage at the lamp bulbs. The illumination varies with the bulb voltage; the lower the voltage the less the light. To obtain the good illumination built into older style headlamps, the owner must have them properly serviced and maintained. This is of great importance for night driving on open highways from the standpoint of safety.

Under very good road conditions with brakes in excellent condition an alert driver takes about 200 feet including reaction time to come to a stop when driving 50 miles per hour at night. With efficient headlamps, objects can



be seen at a distance well in advance of 200 feet, which gives the driver plenty of time to see a pedestrian, parked car, washed out bridge or other obstruction. With inefficient headlamps, the factor of safety is much less. It takes relatively little dirt, oxidation, or traffic film on the reflector to reduce the intensity to the point where the driver may not see an obstruction in time to stop. The new Sealed Beam Headlights are designed to maintain substantially their initial efficiency throughout their life.

It is important to aim the beam of any lighting system to close limits. Moving a car by pushing on the headlamps, minor bumps in traffic and many other things may upset the aiming of the beam. The very small variation in aiming of one degree will change the beam position five feet at a distance of 300 feet down the road. This change, if in the upward direction would throw the full intensity of the light in an oncoming driver's eyes.



TAIL AND STOP LIGHTS

TAIL and stop lights with red lenses to project a warning signal are as carefully designed to project light as are the headlights.

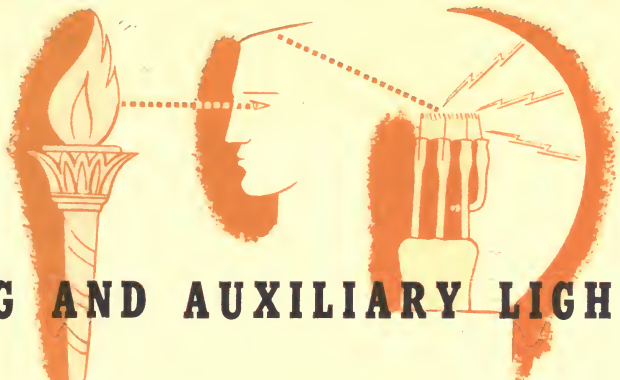
The light from an electric filament of low candlepower is concentrated and projected in a horizontal beam which can be seen for a long distance. The outside shape of the glass may be very complicated to conform to the style of the rear end of the car, but the illuminating engineer has designed prisms into it so that the light travels to the rear and to the side. In addition, it has a

section which will reflect the light from the headlamp of an overtaking car if the tail light bulb burns out. This section is similar to the road signs and markers which are illuminated by the headlamps of oncoming cars. These are made so that light hitting the reflex reflector part of the lens, which has an inside surface made up of many tiny cubes, will be reflected back along the path of the incident light, even though it strikes the cubes at a considerable angle from the side.

Most cars are now equipped with two tail lights. These lights can be used to judge the distance of the car ahead. If the lights are close together, you are far behind. If they spread apart rapidly, you are approaching the car ahead rapidly. If they are wide apart, you are very close.

The stop light which goes on when the brakes are applied has a much stronger beam than the tail light because it must be seen in the daylight. The light source and lenses are designed to give many times as much light in the stop light beam.





FOG AND AUXILIARY LIGHTS

DURING a heavy fog everything moves with caution on land, sea and in the air. Ships reduce their speed, fog horns blow and bell buoys become important in navigating dangerous waters. Airplanes are grounded. Trains slow down. Automobile drivers must likewise proceed with caution.

Fogs and heavy mists are made up of tiny droplets of water. These

droplets vary in size but measurements with the microscope have shown them to be on the order of $1/2,000$ inch in diameter. These tiny droplets hang in the air and are so closely spaced that a headlight cannot penetrate them very far. Each droplet acts as a many-sided mirror which reflects the light back in every direction. The result is the confused glare with



BEAM FROM A TAIL LIGHT

which every driver is familiar.

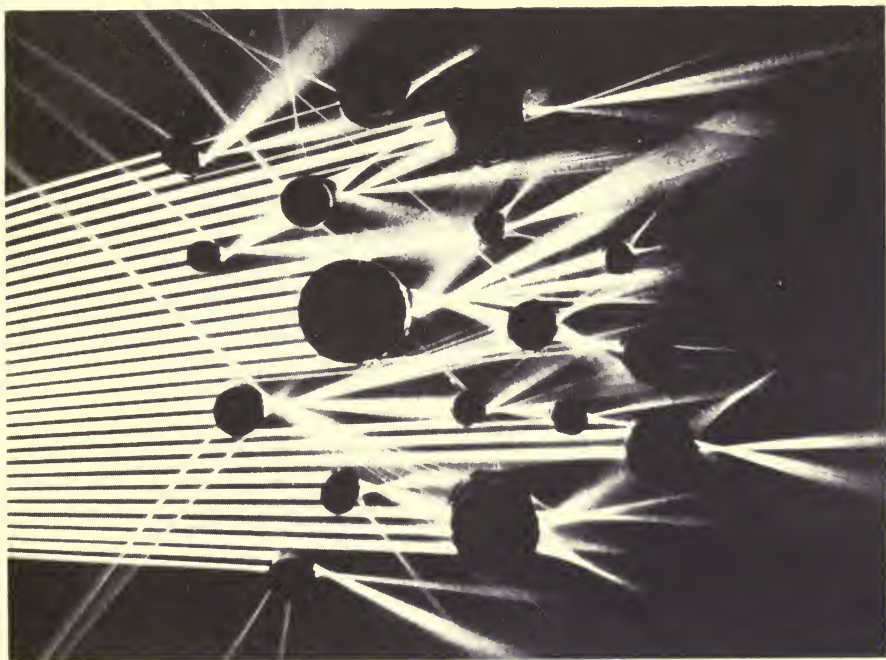
When driving in fog, the upper driving beam of the headlights should never be used. If the light is pointed downward less of the reflections from the fog droplets will be reflected in the driver's eyes. The thinner the layer of lighted fog between the eye and the road, the less it interferes with vision.

Special fog lamps for regions where fogs are common occurrences are often desirable. These lamps are mounted low, at about the bumper level, to reduce the thickness of the layer of lighted fog. The beam cuts off sharply at the top and highly concentrated zones of light are avoided. Caps are put over the bulbs to cut off

stray upward rays. Either yellow or white lenses may be used. In dense fogs, the regular headlamps are turned off. When two fog lamps are used without the headlamps they must be connected to the tail lamps.

Other auxiliary lamps are often desirable, especially on older cars. A passing lamp which directs a half-beam to the right side of the road and above the lower beam will improve the passing light on most multiple-beam headlamps. A driving beam for use on open highways will add light to the upper beam. This lamp directs a concentrated beam somewhat above the upper beam to show up objects far down the road. Such auxiliary driving lights should be





DISPERSION OF LIGHT BY FOG

connected so as to be switched off when the headlamps are switched to the lower beam. Movable spotlights, when properly used, will also assist the headlamps in illuminating far down the road, road signs and the right shoulder.

All of these special lamps are carefully designed, using the fundamental optical principles to give the result desired. Each is as much an example of optical research as are the headlights. Lighting the night from a moving vehicle is a difficult problem. It is only through

industrial research and development that we have the present improved safe lighting devices. Continued research will bring further advancements in the future, as it has in the past.





RESEARCH AND VISION

TO the engineers responsible for good vision in an automobile, night lighting is only one part of the problem, even though it is a very important part. Only a part of the night lighting problem can be solved by the lights on the car. Heavily traveled streets and highways must be illuminated and engineers must design lamps and fixtures which will supply safe lighting. Road signs are an important part of the problem. On several stretches of road, reflex reflectors assist the driver in following the twists and turns, the ups and downs of the road. Reflex reflectors likewise show up obstructions and important road signs.

To study the problems of vision in night and day driving requires constant research on new methods and materials. For the development of headlamps, a long, dark lighting laboratory is required. A test fixture holds bulb, reflector and lens so that the effect of each individual part can be tested and studied. In addition to the laboratory, headlamp cars are used for road tests and demonstrations. These cars are made so that a number of different headlamp units can be mounted on the front and controlled from the driver's seat. Beam patterns are developed on the road at night to determine what is required for seeing. Lamps are then designed in the laboratory to produce this result. In this





manner road testing and laboratory development are correlated.

But it is also important to study the problem of vision through the windshield and windows. In an automobile we are always looking through glass. Even clean glass in windshield and windows will reduce the light one tenth. Dirty windshields may seriously reduce vision. To study this problem of vision, an ingenious device is used. A pair of small electric light bulbs are mounted behind the steering wheel in the position of the driver's eyes. When these lights are turned on, a shadow is cast on a curved checkerboard wall. The illuminated portion is what the driver sees. The dark shadows are the obstructions to his forward vision.

With this device as a tool, engineers have studied the problem of vision and given us cars with less and less of the dark shadows. Careful study has likewise been given to vision through the rear view mirror, resulting in a much better view of what is happening behind our car.

In these and many other ways, automotive engineers study the problems involved in better vision in driving. Each new model is an improvement over the previous one. As new things are developed and new information discovered, they are applied to the automobile. This never-ending work assures you of a constant advancement in the vital problem of vision from your motor car.



By RALPH A. RICHARDSON, Research Laboratories Division
In Collaboration with the Lighting Engineers of General Motors

Cover and Drawings by E. W. Scanes

GLOSSARY OF TERMS

ACETONE—An inflammable liquid originally obtained by the destructive distillation of certain woods, but now made by fermentation of molasses or grain, and synthetically from petroleum gases. Acetone will hold a large percentage of acetylene in solution.

ACETYLENE—The gas given off when water is added to calcium carbide. When acetylene is burned in oxygen a hot flame is produced which is used for welding.

CALCIUM CARBIDE—A compound of calcium and carbon made in an electric furnace. Calcium carbide and water produce acetylene.

CANDLEPOWER—The unit of measurement of a light source. One candlepower is the quantity of light radiated by a standard candle.

COUNTRY-BEAM—The upper beam of an automobile headlamp designed to give a good driving light on an open highway. This beam is used only in country driving when there are no approaching vehicles.

DUCTILE—Capable of being drawn out, as into a wire.

ELECTRIC ARC—A device for producing light which consists of two electrodes separated by a small gap and connected to a source of electricity.

ELECTRO-MAGNETIC WAVES—A family of waves, or radiations, which exhibit similar characteristics. They travel at 186,000 miles a second and can travel through a vacuum. X-rays, light, heat, radio are all electro-magnetic waves.

FILAMENT—A fine, thread-like material. In an electric light bulb the filament is a wire made from tungsten.

FOOT CANDLE—The unit of measurement of the intensity of the light received by an object. One foot candle is the amount of light on a surface one foot away from a standard one candlepower light source.

INCANDESCENT—Made luminous or visible by heat. Carbon particles in a flame, the filament of an electric light and the mantle of a Welsbach gas burner become incandescent and give off light.

LENS—A concave or convex solid section of a transparent material with which light rays are made to converge or diverge.

OPTICS—The science that treats of light and vision.

PARABOLA—A conic section obtained when a cone is cut by a plane parallel to one of its sides. A paraboloid is a solid in which all sections parallel to a certain line are parabolas.

PARABOLIC REFLECTOR—A reflector in which all sections parallel to a certain line are parabolic curves.

PRISM—A wedge or triangular shaped solid made from a transparent material such as glass or quartz with which light rays may be bent or refracted.

RADIATION—The process by which energy is emitted from molecules or atoms. The process of emission, transmission and absorption of radiant energy.

REFLEX REFLECTORS—An optical device that reflects light which may come from an angle and which makes the object appear luminous. Tail lights, road markers and signs use reflex reflectors.

REFRACTION—The bending of light rays when light travels from one transparent medium to another.

TRAFFIC BEAM—An automobile headlight beam aimed downward to prevent the beam from blinding an oncoming driver. This beam is for use in city driving and for passing in country driving.

TUNGSTEN—A heavy, steel-gray element with a high melting point which makes it suitable for filaments in incandescent lights.

For additional copies of this book address
Department of Public Relations
GENERAL MOTORS
DETROIT, MICHIGAN



